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# ANAMORPHIC SITE INDEX CURVES FOR MOESIAN BEECH (*Fagus × taurica* Popl.) IN THE REGION OF ŽAGUBICA, EASTERN SERBIA

## ANAMORFNE KRIVULJE INDEKSA STANIŠTA MEZIJSKE BUKVE (*Fagus × taurica* Popl.) U PODRUČJU ŽAGUBICA, ISTOČNA SRBIJA

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**Summary**

Data on average age and height of dominant moesian beech trees from 109 temporary sample plots were used to establish anamorphic site index curves (SI) calculated from seven growth functions (Chapman-Richards, Korf, Korsun, Hosfeld IV, Todorović, Schumacher and Prodan). The base age for calculation of SI was 100 ($SI_{100}$). The guide curve method was applied. For the evaluation of the models, statistical as well as visual examinations were considered. The results showed that all the applied models had a relatively high coefficient of determination ($R^2$) value, indicating that the models accounted for more than 65% of the variation in the dominant height, which can be considered as large effects. Korsun's function shows the best overall statistics, which makes this model the most suitable for the construction of anamorphic site index curves for the study area.

The obtained results are of importance for effective decision making in forest management planning, forest policy, and ecology in Serbia. Namely, regarding the relatively large sample and well-distributed sample units per age and site classes as well as the source of data (temporary sample plots), the developed site index curves and the method of stratifying the sites according to their productivity were performed for the first time in Serbia. Future studies should be performed in order to expand the knowledge on the dominant beech height-age relationships in the studied region using another well-known procedure of site index construction – polymorphic site index curves and stem analysis data.

**KEY WORDS:** height growth, site index curves; moesian beech; Serbia.

## INTRODUCTION

## UVOD

Beech is the most widespread, and according to environmental, social and economic value belongs to the most important tree species in Europe (Ivanković et al. 2011). In Serbia, moesian beech – *Fagus × taurica* Popl. (*Fagus moesiaca* Domin, Maly/Czeczott.) is the most common and the most important tree species. Based on the data of the National Forest Inventory (Banković et al. 2009), its percentage in the total growing stock is 40,5 %. The growth and increment characteristics of beech follow certain regimes typical

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of deciduous tree species, with changes in the growing and resting periods (Lukić et al. 2003). For example, in the optimal site conditions in Serbia, beech trees can grow more than 45 m in height and 1,5 m in diameter at breast height (Vučković and Stajić 2005). In Croatia, in the best sites conditions beech can reach 37,8 m of mean height at the age of 150 (Špiranec 1975). The distance between the trees and their optimal number, and consequently the optimal size of tree growth space are of great importance for the achievement of the optimal site and stand productivity in beech forests (Lukić 1988; Vučković and Stajić 2003, Zelić 2005).

This species is one of the most productive tree species in Serbia, although its productivity largely depends on silvicultural form and site and stand features. The wide vertical and horizontal distribution of beech on different geological substrates and in various soil evolution stages has caused large differences in the productivity of beech forests (Vučković and Stajić 2005). However, previous studies of pure and mixed stands of beech, as instructed by the mentioned authors, don`t provide enough data for a complete overview and classification of sites and stands according to the actual and potential level of production. Therefore, optimization of the management system of beech forests is extremely important to reach the potential site production and to achieve the most favorable economic and environmental effects (Vučković and Stajić 2003).

Some important drivers of the management system optimization are strongly linked to site and stand productivity issue. It is a well-known fact that some sites support one species and its forest, whilst others support some other species and its forest (Vanclay 1992; Kitikidou et al. 2015). In this sense, site quality assessment represents the evaluation of the natural productive capacity of a forest site for a tree species (Kitikidou et al. 2015). There are various methods of estimating potential site productivity. Generally, tree height is widely used indicator of site productivity. In that context,. Bearing this in mind, the potential productivity of a site has been mostly measured by site index, which is defined as the dominant height of a stand at a base age (Monserud 1984; Sterba and Monserud 1993; Bravo and Montero 2001; Gadow 2002; Skovskaard and Vanclay 2008; Pretzsch, 2009; Zlatanov et al. 2012, Bontemps and Bouriaud 2014; Kitikidou et al. 2015).

Generally, studies on site productivity for even-aged forest have not been carried out very intensively, both in Serbia and partly in the entire Region of former Yugoslavia (except in Slovenia). In Bosnia and Herzegovina, classification of site productivity, for example, has been conducted either by applying the concept of relative-tree height productivity classes, i.e. mean height-diameter relations (Balić et al. 2007) or by relative height site classes, i.e. mean height-age relations (Ibrahimspahić 2004), which were established with simple splitting of tree height variation belt into 5 equal parts. In Croatia, during the process of beech yield table creating, Špiranec (1975) established site classes I-IV based on mean tree height-age relationships for all age classes from the age of 20 to the age of 150. Maunaga (1995) was the first to develop five (I-V) site curves for even-aged spruce stands based on the top stand height-age relations etc.

In the Serbian forest sector, the classification of sites concerning productivity has been carried out using so-called ”site class height chart”, prepared for different types of tree species. They represent a fitted dependence of the height on the breast diameter and site class in the form of a height curve. The number of fitted height curves depending on diameter represents the number of site classes, as well as the number of volume arrays in tariffs (Banković and Pantić 2006).

In spite of the great relevance of site productivity estimates for forest management, studies on site productivity assessment regarding site index curves have hardly been performed in Serbia. Some initial results, although not too representative and in part meaningless, were provided by Ratknić (1998). In order to improve the existing system of site classification according to productivity, harmonize it with the dominant mode of site productivity estimation in Europe and create opportunities for the comparison of the obtained results with the results of site index investigations from other countries where beech occurs, it is necessary to establish the site index curves for this tree species. Accordingly, the study was aimed at (1) modeling the beech dominant height–age relationships and (2) constructing anamorphic site index curves for this tree species in the region of Žagubica, Eastern Serbia.

## MATERIALS AND METHODS
## MATERIJALI I METODE

The study was conducted in beech stands in Žagubica region (about 15000 ha of the total forest area), situated in eastern Serbia. The altitude ranges from 650-1250 m. The parent rock of the management unit consists of limestone and amphibolic and clay shales. Soil types include shallow, medium and deep soils on limestone (rendzina over dense limestone and brownized rendzina over dense limestone) and brown acid soils.

The average annual temperature is 9,8 °C. The mean monthly temperature is the highest in July (20,3 °C) and the lowest in January (-1,0 °C). The average annual precipitation for this location is 682 mm. The wettest months are May and June (with an average of 87 mm and 88 mm, respectively) and the driest are February and March (with an average of 36 mm and 40 mm, respectively).

Temporary sample plots were used to obtain data on average age and height of dominant beech trees necessary for the purpose of determining site indices. A set of 109 temporary sample plots (circular sample plots of 500 m² in size) was established subjectively to cover sites of different productivity quality and age classes throughout the analyzed beech forest complex. Mean age and mean height of 10% of the thickest trees were determined in each experimental plot. The measured height-age data were used to create an average height growth curve (*guide-curve* method) by seven growth functions (Table 2). The parameters of Korsun's, Schumacher's and Prodan's functions were calculated by the least squares method, and the parameters of Todorović's and the other models were calculated by using *Levenberg-Marquardt'* and *Gauss-Newton'* algorithms, respectively.

The appropriate criteria for the selection of the best model are the following:

a) Coefficient of determination: $R^2 = 1 - \left( \dfrac{\sum_{i=1}^{n} \left(h_i - \hat{h}_i\right)^2}{\sum_{i=1}^{n} \left(h_i - \bar{h}_i\right)^2} \right)$

b) Sum of relative squared errors: $SRSE = \sum_{i=1}^{N} \left( \dfrac{h_i - \hat{h}}{h_i} \right)^2$

c) Relative mean squared error (%): $RMSE = \dfrac{\sum_{i=1}^{N} \left( \dfrac{h_i - \hat{h}}{h_i} \right)^2}{N} \cdot 100$

where: $h_i$ is the measured dominant height, $\hat{h}_i$ is the estimated dominant height, $\bar{h}_i$ is the average dominant height and N represents the number of observations in a sample plot.

Since site index (SI) is the dominant tree height at a reference-observed age, previously mentioned functions should go through the given point, i.e. the height at the reference age in order to get the desired site index. This is achieved by calculating a parameter that represents the asymptote of the mentioned functions for each site class separately. The base age for the calculation of SI was 100 ($SI_{100}$). By implementing the above mentioned functions, the so-called anamorphic site index curves were created.

**Table 1.** The sample plots statistics per age class.
Tablica 1. Statističke značajke pokusnih ploha po dobnim razredima

| Sample plots | | | Dominant height of sampled plots tress | | | |
|---|---|---|---|---|---|---|
| Age class | Number of plots | Number of trees per class | Min | Max | Mean | SD |
| <46 | 5 | 28 | 9,3 | 15,4 | 11,09 | 2,45 |
| 50 | 10 | 46 | 10,2 | 19,8 | 15,89 | 2,79 |
| 60 | 10 | 44 | 14,8 | 24,2 | 19,17 | 3,22 |
| 70 | 14 | 50 | 15,8 | 25,3 | 20,40 | 2,92 |
| 80 | 12 | 38 | 22,0 | 29,3 | 26,40 | 2,46 |
| 90 | 16 | 32 | 19,6 | 31,4 | 27,14 | 3,74 |
| 100 | 19 | 22 | 27,2 | 34,5 | 27,22 | 2,98 |
| 110 | 15 | 15 | 18,6 | 36,6 | 27,34 | 4,79 |
| >115 | 8 | 8 | 26,7 | 38,6 | 31,07 | 3,81 |

*Age class "60" means 56-65 years, etc. SD – standard deviation

## RESULTS
## REZULTATI

The main statistical characteristics of the sample plots are presented in Table 1. The table shows that the age and the mean dominant height of the temporary sample plots range from 30 to over 120 and from 9,35 m to 38,5 m, respectively. The oldest tree is 141 years old.

The seven growth functions, their parameter values and the statistics of the fitting to the empirical dominant height-growth data are illustrated in Table 2. The obtained results indicate that Korsun's and Schumacher's functions show the best statistics. They have the smallest SRSE (0,3 and 0,4, respectively) and RMSE (0,31and 0,34, respectively). Functions by Todorović, Chapman-Richards and Hossfeld IV have

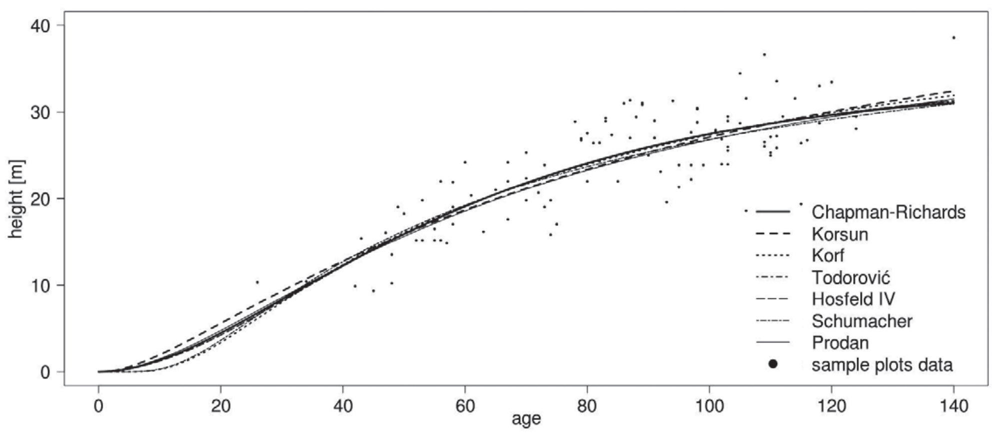


**Figure 1.** The height growth curves parameterized using data from the temporary sample plots.
Slika 1. Krivulje visinskog rasta parametrizirane podacima s privremenih pokusnih ploha.

**Table 2.** The goodness of fit of the applied growth functions for the dominant height-age relationships.
Tablica 2. Statistički parametri uklopljenosti primijenjenih krivulja rasta za odnos dominantne visine i starosti stabala.

| Model | Mathematical formulation | Coefficients | | $R^2$ | SRSE | RMSE |
|---|---|---|---|---|---|---|
| | | Value | Sign. | | | |
| Korf | $H_{dom} = A \cdot e^{\frac{k}{(1-n)\cdot t^{n-1}}}$ | A = 47,4791 | < 0.05 | 0,66 | 3,37 | 3,10 |
| | | k = 47,4438 | Not sign. | | | |
| | | n = 1,9733 | < 0.001 | | | |
| Korsun | $H_{dom} = A \cdot e^{b \cdot \ln t + c \cdot \ln^2 t}$ | A = 0,01238 | < 0.05 | 0,70 | 0,34 | 0,31 |
| | | b = 2,7304 | < 0.01 | | | |
| | | c = -0,2303 | < 0.10 | | | |
| Hossfeld IV | $H_{dom} = \frac{t^k}{c + \frac{t^k}{A}}$ | A = 37,0786 | < 0.001 | 0,66 | 3,29 | 3,00 |
| | | k = 1,9210 | < 0.001 | | | |
| | | c = 65,9653 | Not sign. | | | |
| Chapman-Richards | $H_{dom} = A \cdot \left(1 - e^{-b \cdot t}\right)^c$ | A = 33,3625 | < 0.01 | 0,67 | 3,28 | 3,00 |
| | | b = 0,0242 | < 0.001 | | | |
| | | c = 2,0970 | < 0.05 | | | |
| Todorović | $H_{dom} = b_1 \cdot \left(\frac{b_2}{t}\right)^{-\left(b_3 + b_4 \cdot t\right)^{-1}}$ | $b_1$ = 19,297 | Not sign. | 0,65 | 3,29 | 3,00 |
| | | $b_2$ = 61,123 | Not sign. | | | |
| | | $b_3$ = 0,685 | < 0.10 | | | |
| | | $b_4$ = 0,007 | Not sign. | | | |
| Schumacher | $H_{dom} = A \cdot e^{\left(-\frac{b}{t}\right)}$ | A = 44,30 | < 0.001 | 0,68 | 0,37 | 0,34 |
| | | b = 50,415 | < 0.001 | | | |
| Prodan | $H_{dom} = \frac{t^2}{a + b \cdot t + c \cdot t^2}$ | a = 54,768 | Not sign. | 0,82 | 2,84 | 2,60 |
| | | b = 1,022 | Not sign. | | | |
| | | c = 0,022 | < 0.01 | | | |

* $H_{dom}$ is tree height of dominant trees at the age $t$; $A, b, c, k, n, b_1 \ldots b_4$ are the regression parameters

approximately equal values of statistical indicators. The values of $R^2$ of all the studied models range from 0,65 to 0,82.

In order to further evaluate the proposed models, their visual comparisons in the form of performances in Figure 1 were also carried out. Furthermore, anamorphic site index curve was calculated for each reported model to determine the age and the value of the current height increment at the time of culmination and thus assess the consistency of the model regarding the real situation in the field.

The obtained results indicate that current height increment culminates at the age of 21 (Korsun's model), 25 (Korf's and Schumacher's model), 29 (Champan-Richards' model) and 37 (Todorović's model). Hossfeld IV function proved to be the most unfavorable, with different culmination times and values which is the result of limiting the curve to pass through the desired point or height at the age of 100 (site index).

Although Korsun's and Schumacher's models gave very similar fits, Korsun's equation (a little better overall statistics than that for the Schumacher's one) was chosen as the most appropriate model to assess dominant height-age relations.

The performed site index curves according to Korsun's models are presented in Figure 2.

All modeled function parameters of Korsun's equation are statistically significant. According to the implemented model, the current annual height increment culminates at the age of 21 and the values of the current annual height increment at this age vary from 0,45 m for SI32 to 0,22 m for SI16 (the bottom right corner of Figure 2). The lowest value of $SI_{100}$ is 16 m, while the highest one is 32 m. There are three site classes between these values and the study area has a total of 5 site classes. The difference of 4 m between site index values represents approximately the average standard deviation of the values from the regression line for the age class 100 (90-110).

## DISCUSSION
## RASPRAVA

The optimum utilization of the production capacity of forest communities and forest tree species related to a specific site conditions is of crucial importance for successful

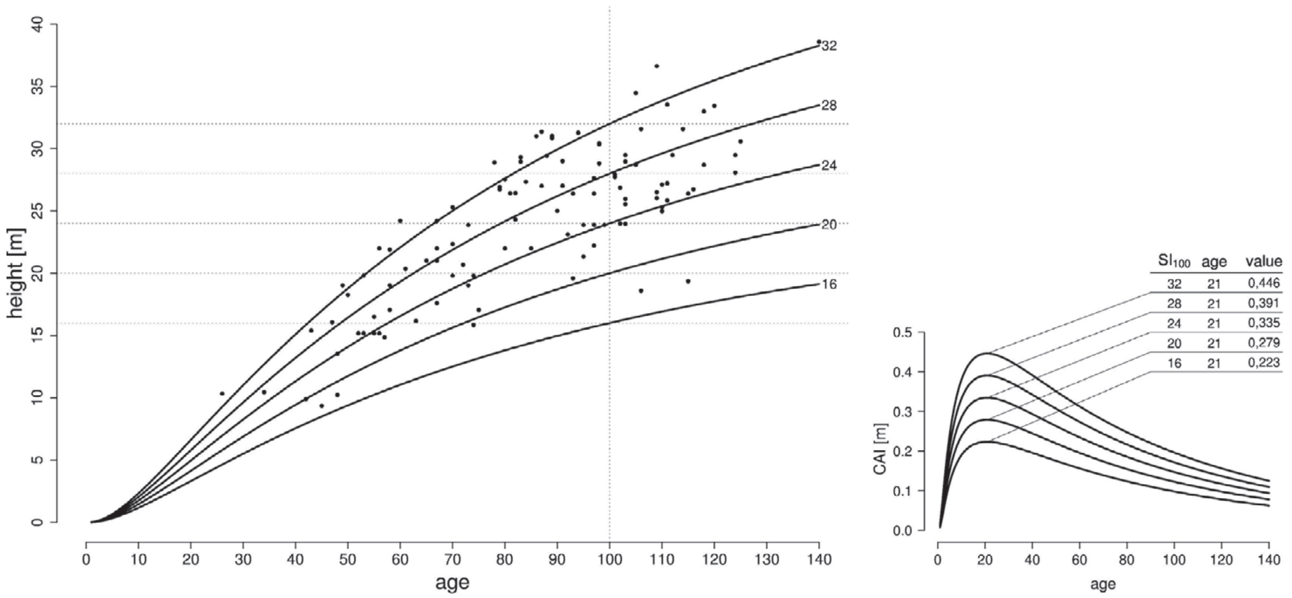


**Figure 2.** Anamorphic site index curves parameterized by Korsun's model
Slika 2. Anamorfne krivulje indeksa staništa parametrizirane Korsunovim modelom

management of forest resources (Zelić 2000). Site index curve is the most commonly used indicator for the estimation and reliability of forest site productivity. Construction of site index curves is a fundamental task in site-quality differentiation and stand development prediction, which gives them great importance in planning and implementing sustainable management of forests. Standard procedures for the construction of site index curves are, however, still lacking (Elfing and Kiviste 1997). In general, site index curves can be calculated using anamorphic or polymorphic procedures. In our study, anamorphic beech site index curves were computed by applying the proportional or guide curve method. This type of site index curves is performed by using the data obtained from temporary sample plots. This type of data is occasionally used to fit site index curves (Walters et al. 1989). The main reason for the use of this data source has been the lack of permanent sample plots in beech forests of this area. It is important to note that when temporary sample plots are used as a data set for the construction of site index curves, it is necessary to provide the appropriate distribution of plots with respect to age and site class. In this context, a set of 109 temporary sample plots established in our study can be considered to be representative enough, because for reliable evaluation of height-age relationships "… *a total of at least of 100 plots is necessary, although more are desirable*…" (Husch et al. 2003). In addition, the temporary sample plots are relatively quite uniformly distributed per age and site classes (except partly in youth and mostly for SI16) to derive representative height growth beech curves for the studied area.

Bearing in mind the fact that the true functional form cannot be known, it is important that the selection is made after a comparison of many functional forms and several criteria (Nanang and Nunifu 1999). Therefore, seven commonly used growth functions were tested in order to find the best model for approximation of dominant height-age relationships. The first obtained results of the conducted analysis showed that all the applied models had a relatively high $R^2$ values, indicating that the models accounted for more than 65% of the variation in the dominant height, which can be considered as a large effect, according to Cohen's (1986) instructions. Furthermore, the model by Korsun and Schumacher showed the best overall statistical features. These results are not absolutely surprising, because Shumacher's model is perhaps one of the most widely used model form in site index curve development (Nanang and Hunifu 1999). However, Korsun's model was preliminary chosen to calculate site index curves, because of a little better model's statistical indicators. Nevertheless, according to Todorović (1961), the three-parameter growth functions (Korsun's one) generally give more realistic performance of relation between a growth element and age than two-parameter functions (Schumacher's one).

In order to further evaluate the applicability of the Korsun's function and the other models used, the average curves constructed by applying these models were graphically presented. The obtained results (Figure 1) show that the lines of Korf's and Schumacher's functions have a very pronounced S-shape and they come out tangentially and almost parallel to the x-axis in the first 10 years of growth. This means that these models, although they are characterized by solid statistical possibilities, have a graphical representation of an unsatisfactory form and that they cannot be fitted appropriately in the real empirical data. Chapman-

Richards's and Todorović's functions have almost identical growth curves and statistical features. Contrary to the observed deficiency in Korf's and Schumacher's functions, which occurs in the initial period of growth curves, the deficiency in Todorović's and Chapman-Richards' functions is linked to the fact that the growth curves of these functions reach asymptote relatively early, though empirical data show upward flow even at the age of 140 (Figure 1). So, although it has been often proved to be very suitable to describe growth in height (Wang and Payandeh 1995; Álvarez González et al. 2005; Zlatanov et al. 2012 etc.), Chapman-Richards' function was not flexible enough to represent the analyzed height growth of beech tress. Also, it seems that the current height increment of Todorović's model (age of 37) is reached quite late. Namely, the culmination of the current height increment of beech at the sites of medium productivity should be expected around the age of 30 (Stajić 2010). Korsun's function proved to be the best one with regard to statistical indicators and growth flow. The only "disadvantage" of Korsun's function could be found in the time of culmination of the current height increment (age of 21), which likely occurs somewhat earlier than in reality. However, it should nevertheless be underlined that in undisturbed stand conditions the height growth of beech can be relatively fast, with a large initial increment (Lukić et al. 2003). Bearing in mind all of the above-mentioned, Korsun's function was definitely selected and the set of anamorphic site index curves was constructed (Figure 2).

As noted, site index studies have not been intensively performed in Serbia. Ratknić (1998) presented beech site indices for the area of western Serbia. In doing so, he applied Todorović's function in fitting the height-age empirical values obtained from the stem analysis method. Ratknić (1998) used the reference age of 150 years for the site index construction, which is considered partly inappropriate given that the currently prescribed rotation length in pure even-aged beech forests in Serbia is less than 150 years. In addition, the culmination of the current height increment on poor sites occurs earlier compared to more productive sites. For example, the culmination of current height increment, according to Ratknić's instructions, occurs for the first three site classes at the age of 30, for the site class VI at the age of 28, and at the age of 24 for the site class VIII. This statement can be considered inadequate according to the present-day knowledge. Namely, it is well known that the better the site, the earlier the current height increment in even-aged stands culminates and the amount at the moment of culmination is greater (Sloboda 1971; Kramer 1988; Vučković 1989; Stajić 2010). By summarizing the available information about the method of site index construction provided by Ratknić, it remains unclear whether the author has developed anamorphic or polymorphic site index curves.

## CONCLUSIONS
## ZAKLJUČCI

The site index curves developed in this study are anamorphic site curves. In the procedure of their forming only asymptote coefficients were changed (shape parameters were constant) resulting in site index curves with the same shape. This fact causes the main drawback of anamorphic site index curves – the same age of the current height increment culmination. It means that the current height increment of different site classes culminates at the same time regardless of the quality of the site. However, this assumption cannot be considered biologically totally justified.

The results of the conducted study show that Korsun' growth model best fits the dominant beech height-age relations and therefore this model was implemented for the construction of site index curves in pure beech stands in the studied region. It must be also noted that the obtained growth model and site index curves should be used within the empirical data set (up to the age of 140). Namely, the model was parameterized on trees whose age in most cases did not exceed 140 years.

Although the determined site indices are burdened with aforementioned limitations, this study is of considerable significance for the Serbian beech forest sector. In a sense, bearing in mind the large sample with mainly well-distributed sample units pre age and site classes, this research is the first extensive research of beech forest sites according to productivity. In addition, this method of stratifying the sites according to quality has been performed for the first time on the basis of site indices calculated from temporary sample plots. The obtained knowledge is useful for effective forest management and decision making in forest management planning, forest policy, and ecology. Of course, future studies should be undertaken in order to expand the database and knowledge on the dominant beech height-age relationships in the studied region and another well-known procedure of site indices construction – polymorphic site index curves – should be applied. In this way, the obtained polymorphic site index curves can be also very helpful in the development of appropriate silvicultural treatments, general classification of sites with regard to their quality and sustainable management of these forests. In that context, the obtained results should be considered as a preliminary stage of site index studies for beech in Serbia.

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## Sažetak

dosadašnja istraživanja i njihovi rezultati u čistim i mješovitim sastojinama mezijske bukve na različitim staništima, kao najrasprostranjenije i najvažnije vrste drveća u Srbiji, nisu dovoljna za potpuno sagledavanje i sistematizaciju staništa i sastojina prema trenutnoj i potencijalnoj razini proizvodnosti (Vučković i Stajić 2005). Postoji više različitih načina utvrđivanja potencijalne proizvodnosti staništa. U tom kontekstu, visina stabala je generalno prihvaćena kao najznačajniji indikator proizvodnosti staništa. S obzirom na to, potencijalna proizvodnost staništa najčešće se utvrđuje preko stanišnog indeksa (eng. *site index* – SI) koji se određuje kao iznos dominantne visine sastojine u određenoj starosti (Monserud 1984; Sterba and Monserud,1993; Bravo and Montero 2001; Gadow 2002; Skovskaard and Vanclay 2008; Pretzsch 2009; Zlatanov et al. 2012; Bontemps and Bouriaud 2014; Kitikidou et al. 2015).

Usprkos velikom značenju evaluacije proizvodnog potencijala staništa za gospodarenje šumama, istraživanja proizvodnosti staništa u vidu stanišnih indeksa nisu intenzivno provođena u Srbiji, ali i u cijeloj regiji zemalja s prostora bivše države Jugoslavije (s izuzetkom Slovenije). U šumarstvu Srbije klasifikacija staništa prema proizvodnosti provodi se pomoću tzv. bonitetnih visinskih grafikona, koji predstavljaju izjednačenu ovisnost visine o prsnom promjeru i bonitetu staništa u obliku visinskih krivulja. Broj izjednačenih linija visina u ovisnosti o prsnom promjeru predstavlja broj bonitetnih razreda, ujedno i broj nizova obujma u tarifama, koji se određuju prema potrebi (Banković and Pantić 2006). U cilju poboljšanja postojećeg sustava klasifikacije staništa prema proizvodnosti, njegove usklađenosti s dominantnim načinom klasifikacije staništa po proizvodnosti i kreiranja mogućnosti za usporedbu dobivenih rezultata s rezultatima ocjene proizvodnog potencijala staništa bukve u Europi, neophodno je definirati krivulje stanišnih indeksa (eng. *site index curves*) za ovu vrstu drveća. Stoga, cilj istraživanja je (1) modeliranje odnosa visine i starosti dominantnih stabala bukve i (2) konstrukcija anamorfnih krivulja stanišnih indeksa za bukvu na području Žagubice u istočnoj Srbiji.Istraživanje je provedeno u bukovim jednodobnim sastojinama u području Žagubice (oko 15 000 ha ukupne površine pod šumom). Nadmorska visina je od 650 do 1250 m. Prosječna godišnja temperatura i količina oborina iznose 9,8 °C i 682 mm. Za utvrđivanje stanišnih indeksa korišteni su podaci o starosti i visinama dominantnih stabala sa 109 subjektivno odabranih privremenih kružnih pokusnih ploha (u cilju pokrivanja cjelokupnog raspona stanišnih uvjeta i dobnih razreda), veličine 500 m$^2$. Na svakoj plohi je utvrđena prosječna starost i srednja visina 10% najdebljih stabala. Izmjereni podaci o visinama u različitim starostima upotrijebljeni su za dobivanje prosječne krivulje rasta u visinu (metoda vodeće krivulje, eng. *guide-curve method*). Prosječna krivulja visinskog rasta je modelirana pomoću 7 različitih funkcija rasta (Tablica 2). Temeljna starost za izračun SI iznosi 100 godina ($SI_{100}$). Kriteriji za odabir najboljeg modela bili su sljedeći: koeficijent determinacije, suma kvadrata relativnih odstupanja i relativna prosječna kvadratna greška (%). Odgovarajućim procedurama dobivene su tzv. anamorfne krivulje stanišnih indeksa.

Prvi dobiveni rezultati provedene analize pokazuju da primijenjeni modeli imaju relativno visoke koeficijente determinacije, ukazujući na to da objašnjavaju više od 65% varijacije u dominantnim visinama, što se prema kriterijima Cohena (1986) može smatrati kao veliki učinak. Između ostalih, modeli Korsuna i Schumachera pokazuju najbolje ukupne statističke značajke. Ipak, Korsunov model je preliminarno izabran za kalkulacije stanišnih indeksa zbog nešto boljih statističkih indikatora. U cilju dodatne ocjene primjenjivosti Korsunove funkcije i ostalih modela, konstruirane su i grafički predstavljene prosječne krivulje visinskog rasta (Slika 1). Korsunova se funkcija pokazala kao najbolja s obzirom na promatrane statističke indikatore i po praćenju tijekova rasta, pa je definitivno izabrana kao model za konstrukciju seta anamorfnih krivulja stanišnih indeksa (Slika 2).

Ovaj rad ima veliko značenje za šumarski sektor u Srbiji i bukvu kao dominantnu vrstu. U izvjesnom smislu, imajući u vidu veliki uzorak s dobro distribuiranim jedinicama unutar različitih starosti i stanišnih razreda, ovo istraživanje je prvo obimno istraživanje proizvodnosti bukovih staništa. Uz to, primijenjena metoda stratifikacije staništa prema proizvodnosti je po prvi puta provedena na bazi stanišnih indeksa dobivenih s privremenih pokusnih ploha. Dobivena saznanja imaju praktičnu primjenjivost u okviru gospodarenja šumama, kao temelj za donošenje odluka na polju planiranja, šumarske politike i ekologije. Naravno, potrebno je provoditi daljnja istraživanja u cilju proširivanja baze podataka i saznanja o odnosu između dominantnih visina i starosti u bukovim sastojinama u proučavanom području, kao i pristupiti konstrukciji polimofrnih krivulja stanišnih indeksa. Na taj način polimorfne krivulje stanišnih indeksa bile bi također vrlo korisne i u određivanju odgovarajućih uzgojnih tretmana, općoj klasifikaciji staništa s obzirom na njihovu kvalitetu i za implementaciju načela potrajnog gospodarenja šumama.


**KLJUČNE RIJEČI**: visinski rast, visinske krivulje, mezijska bukva, Srbija